ASSESSING CONSERVATION VALUE OF ISLANDS IN THE CENTRAL SEYCHELLES

BY

MICHAEL J. HILL[1]

ABSTRACT

Data gathered in the island assessment process are used to prioritise the islands visited (and, by extrapolation, other islands in the central Seychelles) for conservation value, particularly in regard to conservation of endemic land birds. Several criteria of particular importance for endemic bird conservation are identified, and these could be used in more rapid assessment of other islands in the area for conservation.

INTRODUCTION

Several authors have attempted to formalise criteria to evaluate land for conservation purposes in order that the most appropriate sites can be selected for protection (see, for example, Smith and Theberge, 1986; Usher, 1986). There is no simple consensus that can be applied in all situations although a number of biological and physical indicators that are commonly cited include the presence of rare species of animals and plants, or rare habitats, diversity (of species or habitats), size, "representativeness" or "naturalness", and the relative fragility of an area or habitat (Bibby, 1998). In addition, social, cultural and management practicalities need to be considered, especially where an area has multiple use (such as scientific research or recreation in addition to conservation).

While many criteria emphasise existing conservation values, the concept of "potential value" (Ratcliffe, 1977) or, in this case, "rehabilitation value", is particularly important for the islands of the granitic Seychelles. The original habitats of all islands have been profoundly altered in the past 200 years. Active human intervention is likely to be necessary to realise the conservation value of any of the small or medium-sized islands. However, the term *restoration* (implying a return to the original state) is probably inappropriate for any such process involving the removal of alien species and introduction (or re-introduction) of native species. Instead, a partial restoration or *rehabilitation* is probably the most that can be achieved (Simberloff, 1990). The original vegetation and habitats of the smaller islands are likely to remain the subject of speculation; written records of island biota prior to human settlement are patchy and equivocal in nature and, while a fossil record may exist, conditions for preservation of biological remains such as pollen are more likely to occur on the larger, wetter islands.

[1] Nature Seychelles, PO Box 1310, Mahé, Seychelles. E-mail: birdlife@seychelles.net

The island assessment procedure quantified various aspects of the current flora and vegetation, and fauna of the islands visited and these data can be used to develop priorities for island (and species) conservation in the Seychelles. In this report, data gathered on the 10 islands described in individual island reports will be considered.

A large number of biological factors need to be considered in determining priority islands for conservation. Major factors include:

1) island size;
2) proximity of other islands;
3) island topography;
4) range of habitats (existing and potential);
5) extent of natural or near-natural vegetation (existing and potential);
6) existing biodiversity values;
7) invertebrate prey availability (existing and potential);
8) presence/absence of invasive introduced animals;
9) presence/abundance of invasive introduced plants;
10) pollutants and pathogens (existing and potential).

BIOLOGICAL AND PHYSICAL FACTORS

Island Size

Island size is an important factor contributing to conservation value, through its influence on biological/historic features including:

- potential populations of endemic species;
- possibility of successful eradication of introduced species (human population also important);
- range of available habitats and climate (geology, altitude range also important);
- history of exploitation (accessibility, human population also important).

Drawing on the theories of island biogeography (MacArthur and Wilson, 1967), it is often recommended that protected areas should be as large as possible to protect larger populations of individual species and to maximise the number of different species protected (Bibby, 1998). Larger populations are less vulnerable to extinction through stochastic events than smaller populations and may contain greater genetic diversity than smaller populations (Lande & Barrowclough, 1987).

The central Seychelles is a small, isolated archipelago with a high degree of endemism among its species (Nussbaum, 1984b). The granitic islands, together with Bird and Denis, have a total land area of only 23,140 ha (approximately 90 square miles) (Seychelles Survey/Directorate of Overseas Surveys, unpublished data). This small potential range means that technically all endemic birds of the Seychelles qualify as threatened under IUCN criteria (Collar *et al.,* 1994). Within the granitic Seychelles, island size varies considerably. Although there are over 40 islands (excluding unvegetated rocks), most are very small (Fig. 1). Only four islands exceed 1,000 ha in size and the largest individual island, Mahé, accounts for 66% of the total land area.

While the largest islands of the Seychelles would appear to offer greatest potential for conservation, several factors act to reduce their importance for conservation of endemic land birds. Mahé, Praslin and La Digue all have large human populations and associated problems: multiple ownership, pressure of development (especially important on coastal plateaux), the presence of large populations of domestic and feral animals, and regular traffic of cargo between islands (increasing the probability of transfer of alien predators and exotic plants). This increases the difficulty of eradicating introduced mammalian predators and the likelihood of re-invasion.

The smallest islands, and even some of the unvegetated rocks, may have considerable conservation value as many have escaped the introduction of introduced predators and few have human populations. Such islands are of greatest value as nesting sites for seabirds and for some species of native reptiles and invertebrates that can tolerate arid conditions but cannot survive in the presence of introduced predators.

The island assessment work concentrated on small- to medium-sized islands (between 28 and 286 ha in size) which offer some of the benefits of smaller islands (single ownership, small or no human population, potential for eradication of introduced species) but are large enough to support viable populations of endemic birds. Within the size range considered, larger islands are likely to offer the greatest opportunity for rehabilitation of a range of native ecosystems and endemic species.

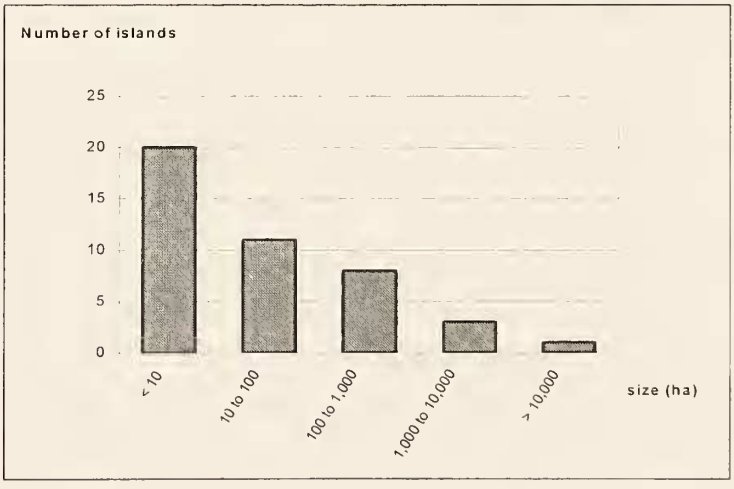

Figure 1. Size distribution of islands in the central Seychelles.

Proximity of Other Islands

The proximity of other islands helps to determine the rates of invasion by species (MacArthur and Wilson, 1967). Neighbouring islands can act as a source of invasion, especially by mobile organisms such as birds (and hence, for example, bird-distributed plant species). The proximity of Thérèse and Conception to the island of Mahé (which supports most of the endemic plants of Seychelles) probably contributes to the large number of endemic plant species on these small islands.

In theory, a cluster of small proximate islands under conservation management could provide important conservation benefits, especially for vagile organisms such as

birds. Occasional natural transfer of individuals between islands could ensure continued gene flow between populations and allow populations to function as a single, large population (such transfers have been observed in Seychelles magpie-robin: Shah and Parr, 1999). This might be particularly important for Seychelles birds; eradication of introduced pests and management for conservation is much easier on smaller, rather than large, multiple-owner islands. Groups of proximate islands could be gradually established a part of a long-term conservation strategy.

Proximity does, however, carry a number of disadvantages; in particular, it allows the spread of diseases and the invasion of exotic species. Thérèse Island, less than 1 km from Mahé, has an established infection of takamaka wilt disease, while Conception, further from the mainland, does not (although takamaka trees are found there). But proximity alone cannot determine invasion of such harmful species. Factors such as wind direction also play a role in dispersal/invasion: North Island, 7 km from Silhouette, has both takamaka wilt and the invasive weedy shrub *Clidemia hirta*, both probably invaders from Silhouette (carried by mobile vectors). Some invasive species are carried by human vectors, for example the crazy ant *Anoplolepis gracilipes*, carried to new islands with plants or other cargo. In this case, the amount of human traffic (and the nature of cargoes moving between islands) will influence invasion to a greater extent than absolute distance.

Island Topography

Island topography (range of altitudes, presence/absence of "plateau") has an important influence on the rehabilitation potential of islands.

In general, maximum island altitude is closely correlated to island size (Pearson Correlation Coefficient = 0.828; $p < 0.001$). For larger islands such as Mahé, altitude has an important influence on rainfall; rainfall is greater at higher altitude stations and also at lower stations that are not in the rain shadow of hills (Walsh, 1984). Constant high humidity and high rainfall allow mist forests to thrive on the hills of Mahé and Silhouette. However, on smaller (lower) islands altitudes are probably less important in determining climate. More important factors influencing the length and severity of dry seasons include an island's position relative to high islands (rain shadow effects, etc.) and its position within the archipelago (islands to the north have a shorter dry season than those further south: Walsh, 1984). Maximum altitude alone is a probably poor indicator of rehabilitation potential for islands.

However, topography (and, in particular, size of plateau) has a greater degree of biological importance. The plateaux are composed of recent (less than 6,000 years old) calcareous deposits. On some islands (including Cousin, Frégate, Bird) these have combined with guano to form cemented sandstone (Braithwaite, 1984). In addition to the calcareous deposits of plateaux, alluvial deposits occur at the mouth of rivers and streams. These conditions are rare on small islands and tend to be marked by mangrove habitats. The alkaline soils of plateaux are generally more fertile than those of uplands (Braithwaite, 1984). The productivity of terrestrial invertebrates appears higher in plateau habitats than on hills, so birds feeding on ground invertebrates (such as Seychelles magpie-robins) are likely to reach greater densities on plateaux and islands with large plateaux to support larger populations.

Plateaux are also easier to manage effectively than hill habitats. While plateau woodland can be dense (especially where there is heavy regeneration of coconut), plateaux are not physically inaccessible as rocky slopes and glacis can be. Figure 2 shows the extent of land in altitude categories for all islands studied. Table 1 has approximate extents of true coastal "plateaux" (areas of predominantly coralline deposits of altitude 5 m asl or less).

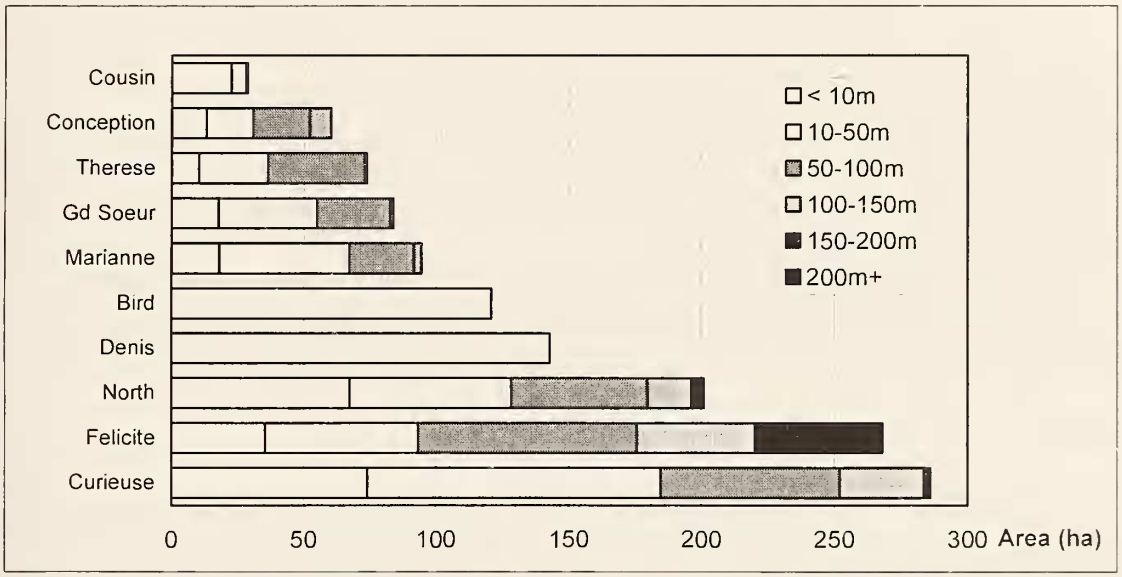

Figure 2. Altitude distribution of land area.
From maps of Seychelles, Directorate of Overseas Surveys/Seychelles Survey.

Table 1. Area of coastal plateau. Figures in parentheses = area excluding mangrove habitats.

Island	Approx. area (ha.)
Denis	143
Bird	121
North	49
Curieuse	48 [39]
Cousin	19 [18]
Félicité	4
Grande Soeur	4
Thérèse	3
Marianne	2
Conception	0

Coralline islands are similar to the plateaux of granitic islands; Denis Island even has freshwater marsh, a feature of coastal areas on granite islands. Of the granitic islands, those with the largest plateaux are Curieuse and North islands. For both these islands, the

plateaux alone are larger than an island such as Conception. Although Félicité is larger than North, it has a significantly smaller plateau and is a much higher island. This may explain why Félicité has a number of endemic plant species not present on North Island (see "Existing Biodiversity Values", below).

Range of Habitats

Habitat diversity is a commonly used criterion for ranking land for conservation purposes (Bibby, 1998). In general, it is felt preferable to conserve areas with the widest range of habitat types. The greater the number of habitats protected, the greater are the opportunities to preserve a wide range of plant and invertebrate species (although not all habitats are equally important to conservation: see below). However, small islands cannot conserve all the habitats represented in the Seychelles; high-altitude biomes are entirely unrepresented on the islands assessed.

In general, larger islands have a greater range of habitat types than smaller ones and granitic islands have a larger range of habitat types than coralline islands of similar size.

Extent of Natural or Near-Natural Habitats

All islands in the granitic Seychelles have been altered (usually to a large extent) by human intervention and the greatest change has occurred at middle to lower altitudes (below about 500 m). Thus, there are no examples of small, pristine islands to act as blueprints for island restoration, and records of early travellers offer little useful information. The original vegetation and habitat structure of islands cannot be exactly reconstructed. However, habitats can be broadly classified according to their degree of "naturalness"; most islands have been cleared for coconut plantation and, where this has fallen into disuse, the regenerating forest and scrub habitats are dominated by either introduced or native species. "Near-natural" habitats can be defined as those dominated by native species, in vegetation types which would persist on islands prior to human interference (usually, woodland or scrub). Generally, islands with a greater number of different near-natural habitats and larger areas of near-natural habitats should be preferred to those which are dominated by anthropogenic habitats. Of these habitats, woodland is probably the most important for endemic birds.

Table 2 shows the approximate extent of near-natural habitats on the islands studied. Habitats are separated into native woodland, scrub (including beach crest vegetation), mangrove and other wetland. Wetlands, especially freshwater wetlands, have conservation importance for a number of reasons:

- They provide habitat for a number of endemic freshwater invertebrates and vertebrates (Stevenson *et al.,* 1997);
- Invertebrates with aquatic larvae often have winged adults which may be taken as food by endemic insectivorous birds (e.g. black paradise flycatcher; Watson, 1991); and
- They are nationally threatened (since most wetlands in Seychelles are small, they are easily threatened by pollution, drainage and other human impacts: Stevenson *et al.,* 1997; Shah, 1997).

Table 2. Approximate extent of near-natural habitats on islands studied.

Island	Area (ha)				
	Native woodland	Native scrub (including beach crest veg.)	Mangrove	Other wetland	Total
Bird	18	50	0	0	68
	0	4	0	0	4
Cousin	20	4	1	<1	25
Curieuse	55	87	5	1	148
Denis	28	6	0	<1	34
Félicité	131	2	0	< 1	135
Grande Soeur	21	1	0	< 1	22
Marianne	7	7	0	< 1	14
North	16	1	0	1	17
Thérèse	2	1	1	< 1	4

The largest extent of near-natural habitats is on Curieuse which has the most woodland/scrub and the greatest area of wetlands.

Existing Biodiversity Values

Biological diversity is one of the most frequently used measures of conservation value (Bibby, 1998). It can be expressed as the total number of species (species richness), or (more useful for conservation purposes) the number of endemic, restricted-distribution or threatened species (Stattersfield *et al.,* 1998). Because areas of high biodiversity for different taxonomic groups often overlap (Bibby, 1998), conservation of areas of high biodiversity value in well-studied groups will often lead to conservation of less well-known taxa. Thus, in Seychelles, many endemic invertebrates are associated with endemic plants (especially palms and *Pandanus* species). During the island assessment work, species lists were made for a number of different taxonomic groups, the most complete being for plants and land birds. The importance of islands for conservation of these groups is compared below.

Plants. The majority of plant species identified were exotic. Of 428 species identified, at least 262 (61.2%) are non-native. However, the proportion of the total flora composed of exotic species varied between islands (Table 3). In general, the islands that have the greatest proportion of exotics are coralline islands with a restricted natural flora (Bird, Denis), or those with a history of agricultural production (North). Islands with no permanent human population (Thérèse, Conception, Marianne) tend to have floras less dominated by exotic species.

Table 3. Composition of angiosperm flora of central Seychelles islands.

	Total no. species	Percentage of total flora		
		Introduced	Native	Endemic
Bird	103	68.9	21.4	0
Conception	84	44.0	41.7	10.7
Cousin	92	51.1	34.8	2.2
Curieuse	230	57.0	35.2	10.0
Denis	174	68.4	21.3	0
Félicité	175	49.1	41.7	13.1
Grande Soeur	116	57.8	32.8	5.2
Marianne	146	53.3	32.9	5.5
North	175	61.7	24.0	1.1
Thérèse	173	53.7	37.1	9.7

The plant species of greatest conservation concern are those endemic to the Seychelles and a small number of species that, while not endemic, are threatened with extinction nationally or globally. Procter (1974) recognised 72 species endemic to the Seychelles, but some of these taxa were revised by Friedmann (1994). Carlström (1996a) suggests that the original number of endemic taxa found on the islands was 84 of which eight are now extinct.

Endemic species can be found in a range of habitats from sea level to the highest peaks although the largest number of species are found at intermediate altitudes, 300 – 600 m above sea level (Carlström, 1996a). Most of the smaller islands in the archipelago are lower than 300 m at the highest point and their potential endemic flora is therefore restricted. In addition, environmental change on small islands has tended to be more complete than on the larger islands which may have led to local extinctions of more specialised endemics.

In the current survey, 31 endemic taxa (27 full species, four subspecies or varieties) were recorded. No endemic plants were recorded on the two coralline islands Bird and Denis. On the granitic islands the number of endemic taxa ranged from two (on Cousin and North Islands) to 23 (on Curieuse and Félicité). The most widespread endemics were *Pandanus balfourii* and *Ficus reflexa* ssp. *seychellensis* which occurred on all of the granitic islands surveyed. While larger islands tend to support a greater number of endemics than smaller ones, other factors also appear important including distance to large islands and environmental history.

In addition to her work on threatened endemic plants of the granitic islands, Carlström (1996a) identified 16 native (non-endemic) species that she regarded as threatened on the basis of declining population and/or small area of occurrence within Seychelles. Three of the species concerned were identified in the current study, *Lagrezia madagascariensis* ("Critically endangered") on Conception, *Disperis tripetaloides* ("Vulnerable") on Marianne, Grande Soeur, Curieuse and Thérèse; and *?Tylophora coriacea* ("Vulnerable") on Denis. However, given the previous paucity of data on the distribution of plants (especially inconspicuous herbs such as *L. madagascariensis* and *D. tripetaloides*) on smaller islands of Seychelles, the designation of these three species should be regarded as provisional. *D. tripetaloides,* in particular, appears relatively

widespread although probably often overlooked due to its small stature and ephemeral flowering stems.

Land birds. The short period of time on each island did not allow a comprehensive list of migrant and vagrant species to be made but most resident species were recorded. In total, 37 species of land birds (including waders and herons) were recorded. Of these, two were vagrants, 14 were migrants and 21 were resident species. Of the resident birds, 10 species were endemic, six introduced and five native. However, the only ubiquitous species were four introduced birds: barred ground dove *Geopelia striata*; Madagascar turtle dove *Streptopelia picturata*;, common mynah *Acridotheres tristis*; and Madagascar fody *Foudia madagascariensis*. Five endemic species were recorded on only one of the islands surveyed. The most widespread endemic birds were Seychelles blue pigeon *Alectroenas pulcherrima* (nine islands) and Seychelles sunbird *Nectarinia dussumieri* (eight islands).

For resident land birds, there is no significant relationship between island area and the number of resident species. However, there is a linear inverse relationship between the species richness and distance to the nearest large island (defined as islands over 1000 ha) ($p = 0.030$) and a similar relationship with distance to the nearest island of any size ($p = 0.049$). These results contrast with those of Diamond (1984), who found that isolation was a better predictor of *original* species richness of bird communities but not significant for *current* species richness which was better explained by island area. However, Diamond omitted some islands such as Cousin and Cousine from his calculations on the basis that they were too close to Praslin to be treated as independent.

In fact, species number alone gives little insight into the conservation importance of islands. North Island supports the same number of native species as Cousin, but whereas Cousin has five endemics, including three endangered endemics, only three endemic species were recorded on North Island and one of these species (Seychelles Swiftlet *Collocallia elaphra*) did not appear to be normally resident. Table 4 shows the number of endemic land bird taxa (species and subspecies) recorded on each island, and ranks the islands studied for importance.

Table 4. Number of endemic and threatened species (plants and birds) identified.

	No. endemic plants	No. threatened native plants	Rank (plants)	No. endemic land birds	Rank (birds)
Bird	0	0	10	0	11
Conception	9	1	4	3	5
Cousin	2	0	7.5	5	1
Curieuse	23	1	1	3	5
Denis	0	1	9	1	10
Félicité	23	0	2	2	8.5
Grande Soeur	6	1	6	2	8.5
Marianne	8	1	5	3	5
North	2	0	7.5	3	5
Thérèse	17	1	3	3	5

There is no significant correlation between endemic plant and bird richness (Spearman rank correlation coefficient $r_s = 0.418$, $p>0.10$). The lack of correlation between importance ratings for plants and birds stems from the different factors underlying their distributions. For several endangered endemic land birds (including Seychelles magpie-robin, warbler and fody) the primary factor determining current distribution appears to be introduced mammalian predators, principally cats and rats. The distribution of endangered endemics is thus partially a relict (due to survival of birds on predator-free islands such as Frégate and Cousin) and in part an artificial construct as further islands (such as Cousine, Aride) were freed of introduced predators and endemics translocated. Predation may also play a role in the decline of endangered endemic plants through the destruction of flowers and fruit before maturity (Carlström, 1996a). However, direct predation appears to be less of a threat to the survival of plant species than it is to birds. Grazing mammals, such as goats, are not presently a threat to endangered plant communities in the granitic Seychelles. The major threats to endemic and endangered plants are habitat destruction and invasive plants (Fleischmann, 1997), although for certain species direct exploitation may also be significant (Shah, 1997).

However, although the ranking of islands for bird and plant conservation differ, there are some similarities between the lists in Table 4. The coralline islands Bird and Denis, which are remote from other islands in the archipelago, have low habitat diversity and were most comprehensively affected by human intervention, emerge as the islands with lowest biodiversity rating for both groups. While restoration of granitic islands of the central Seychelles may include the enhancement of existing endemic floras, this would probably be inappropriate on the coralline islands. The lack of endemic species would not in itself prevent these islands being used for translocations of endemic birds (indeed, it might allow a greater degree of environmental intervention prior to translocation and would eliminate the possibility of negative interactions between translocated and pre-existing endemic taxa) but would probably reduce the overall conservation gain.

Invertebrate Prey Availability

Invertebrates were collected using several different methods to provide data on prey abundance for insectivorous birds. The techniques giving comparative data of greatest importance for endemic birds are pitfall trapping and leaf-invertebrate counts.

Pitfall trapping. Results suggested that invertebrate density was highest on coralline islands, followed by the plateaux of granitic islands. Hills on granitic islands had lower invertebrate density. There appeared to be no significant association between vegetation parameters and the pitfall catch, although trapping was carried out within a narrow range of conditions (in woodland and scrub). While the taxonomic composition of assemblages on coralline islands differed from those on most granitic islands, they were similar to those on Cousin Island (which already supports a population of Seychelles magpie-robin). This suggests that the priority islands for Seychelles magpie-robin introduction are the coralline islands (Denis, Bird) or islands with large plateaux (Curieuse, North) irrespective of the nativeness of their vegetation.

However, invertebrate density is only one aspect of magpie-robin feeding ecology. Food availability is also dependent on the suitability of habitat for feeding. On Frégate, magpie-robins feed primarily in open areas free of herbaceous vegetation (Watson *et al.*, 1992). On Denis Island, herbaceous and shrub layer vegetation was generally dense with little ground free of ferns (*Nephrolepis* and *Phymatosorus*) and young coconuts *Cocos nucifera*. Management of Denis Island's vegetation would be necessary before introduction. On Bird Island, the high density of crazy ants *Anoplolepis gracilipes* is likely to influence magpie-robin behaviour, possibly disrupting feeding and nesting.

Leaf invertebrate counts. These counts give information on the food availability for small insectivorous birds including Seychelles warbler, paradise flycatcher and white-eye. The density of invertebrates on leaves varies greatly between wet and dry seasons but, in general, native plants have a higher density of invertebrates associated with them than do introduced species. Densities of invertebrates on *Morinda citrifolia* are comparable with those on native rather than introduced species. There is no significant difference in invertebrate density between trees in hill and plateau locations. Islands with the greatest potential food supply for small insectivorous species are those with the largest number of native trees (Félicité, Curieuse). However, the smallest island studied (Cousin) supports a population of Seychelles warbler suggesting that (with habitat restoration) any of the islands studied would be large enough to support this species.

Presence/Absence of Introduced Animals

Animal communities of remote oceanic islands tend to be more susceptible to invasion than communities on continental land masses (Elton, 1958) and introduced species of animals and plants have a disproportionately large impact upon island ecosystems (Williamson, 1996). Exotic species can have far-reaching effects; introduced animal species, through patterns of grazing and predation, often favour the establishment and spread of exotic plant species over native flora (Stone *et al.*, 1992). In general, only a small proportion of alien species become established as serious pests. However, since there are no native terrestrial mammals in the Seychelles, it is likely that all of these species have an impact upon natural communities (Racey and Nicoll, 1984).

In addition to mammals, animal introductions to the granitic Seychelles have included birds (seven species established; Diamond, 1984; Skerrett *et al.*, 2001), reptiles and amphibians (at least four species established; Cheke, 1984; Nussbaum, 1984a and b), freshwater fish (one or more species established) and an unknown number of invertebrate species. For many of these species, it is impossible to assess their ecological impact. Information is more complete for the more conspicuous vertebrates, particularly mammals and birds.

In Seychelles, the mammal species with the greatest ecological impact are cats *Felis catus* and rats *Rattus* spp., which are predators of native species and (to a lesser extent) rabbits *Oryctolagus cuniculus*, which can destroy native vegetation. Cats and rats are widely established on islands in the archipelago and were among the earliest introductions to the islands; cats and ship rats *Rattus rattus* were probably first introduced around the time of the earliest permanent human settlement of the Seychelles in the late eighteenth century. The Norway rat *Rattus norvegicus* is a more recent introduction with

a relatively restricted distribution (Hill, in prep). These alien predators have long been associated with the loss of endemic birds (Newton, 1867: Diamond, 1984). Rats and cats have been implicated in the extinction of at least 27 populations of Seychelles land birds (Diamond and Feare, 1980). Feral rabbits are today restricted to one small seabird island, although domesticated animals are commonly kept in captivity on larger islands. Other alien mammals are less destructive or less firmly established: these include black-necked hares *Lepus nigricollis*, mice *Mus domesticus,* tenrecs *Tenrec ecaudatus*, dogs *Canis familiaris*, cattle *Bos taurus* and pigs *Sus domesticus*.

Of the small number of introduced land bird taxa surviving in the Seychelles, several appear to have minimal impact on native species. Three species (barred ground-dove *Geopelia striata,* common waxbill *Estrilda astrild* and Madagascar fody *Foudia madagascariensis*) are largely restricted to open, anthropogenic habitats. The Madagascar turtle dove *Streptopelia picturata picturata* appears to have caused the effective extinction of the endemic race of the same taxon (*S. p. rostrata*) but there is no evidence of ecological differences between the races so any effects on other species are likely to be limited. The most recent land bird species to become established, the ring-necked (rose-ringed) parakeet *Psitticula krameri* appears restricted in population and ecological influence at present (Skerrett *et al.,* 2001).

Two introduced bird species with important ecological effects in near-natural habitats are the barn owl *Tyto alba* and common mynah *Acridotheres tristis*. Barn owls were introduced from East Africa in 1949-52 (Blackman, 1965) in an unsuccessful attempt to control introduced rats. In addition to rats, they take most small birds (in particular, fairy terns *Gygis alba*: Penny, 1974). Mynahs are omnivorous but are nest predators of Seychelles magpie-robin (McCulloch, 1996) and possibly other endemic bird species.

There are many introduced invertebrate species in the Seychelles, some deliberately introduced to provide biological control of agricultural pests (for example, beetles of the family Coccinellidae to control scale insects on crop plants) while other introductions were accidental. At least one introduced invertebrate is known to have important deleterious effects to conservation: the crazy ant *Anoplolepis gracilipes* (Haines *et al,* 1994; Hill in prep). Table 5 shows the distribution of six introduced animals of particular conservation concern, between islands studied.

Table 5. Introduced animal species present on the islands assessed.
Bir = Bird; Con = Conception; Cou = Cousin; Cur = Curieuse; Den = Denis; Fel = Félicité; GSo = Grande Soeur; Mar = Marianne; Nor = North; The = Thérèse
+ = present; (+) = present early 2000, probably eradicated by mid-2001; ? = probably present but not recorded during island assessment survey

	Bir	Con	Cou	Cur	Den	Fel	GSo	Mar	Nor	The
Felis catus	-	+	-	(+)	(+)	+	+	+	+	+
Rattus norvegicus	-	+	-	-	-	-	-	-	-	-
Rattus rattus	-	-	-	+	+	+	+	+	+	+
Acridotheres tristis	+	+	+	+	+	+	+	+	+	+
Tyto alba	-	?	?	+	-	?	?	?	+	?
Anoplolepis gracilipes	+	+	+	-	+	+	-	+	-	+
TOTAL	2	4-5	2-3	3	3	4-5	3-4	4-5	4	4-5

The presence/absence of species on islands does not fully reflect their conservation impact except perhaps for mammalian predators. For non-mammals, density of populations (and hence, impact) may vary greatly between islands. Thus, while *Anoplolepis gracilipes* forms vast colonies and dominates near-natural habitats on Bird Island, it is widely present on other islands without having such severe impacts. The common mynah is found on all islands but is rather rare on Cousin. In the case of cats and ship rats, however, there is usually a simple relationship between the presence of the species on an island and the loss of susceptible native bird species.

Although introduced mammals have a great impact upon native species, it is feasible to eradicate populations. The removal of alien predators in the Seychelles has been directly responsible for the continued survival of at least one endangered endemic bird species, Seychelles magpie-robin. The last surviving population of this species was threatened by the introduction of cats to Frégate in 1958. In 1960, over 80 cats were killed (Penny, 1968), clearing the island of mammalian predators (at least temporarily). In New Zealand, cats have been eradicated on islands as large as 3,000 ha (Veitch and Bell, 1990). Only two of the granitic Seychelles exceed this size (and both of the large islands have permanent human populations, making it difficult to eradicate cats). In July-August 2000, rat and cat eradication was attempted on three medium-sized islands in the Seychelles archipelago, by Don Merton and colleagues from the New Zealand Department of Conservation. Anticoagulant baits were applied aerially (for rats) and ground-baiting and trapping were used to remove cats from Curieuse and Denis Islands. On Frégate Island, only rat baiting was used (no cats present). Cats appear to have been successfully eradicated on Curieuse and Denis and Norway rats on Frégate but, by mid-2001, ship rats were again recorded on Curieuse and Denis. It is not clear whether eradications were unsuccessful on these islands, or these rats represent subsequent reinvasion.

Invasive Weed Species

On most small islands of the Seychelles the flora is dominated by introduced species which form 44-69% (or more) of the plant list on the islands studied. Procter (1984) estimated that nationally around 165 exotic plant species had become established in the wild (forming 22% of the flora) and a further 249 (33%) were known only in cultivation. The latter figure has certainly increased as new species are constantly being added to the garden flora of Seychelles (Shah, 1997). Globally, only a small proportion of introduced species become established in wild communities with only 10% of introduced, established species becoming pests in their new environment (Williamson, 1996). Procter's figures suggest that a higher-than-expected proportion of species imported into Seychelles have become established, perhaps due to Seychelles climate or the relative invadability of species-poor island vegetation, especially when modified by human activities.

It is difficult to estimate the number of exotic species that have become serious invasive weeds in the granitic Seychelles in part because weediness is hard to define in the context of some fundamentally altered ecosystems. Thus, while agricultural weeds are easily identified, as are species invading largely natural ecosystems (such as glacis habitats which may be invaded by *Alstonia macrophylla:* Carlström, 1996a), in most mid-

altitude forests on the large islands native trees have been replaced by exotic plant species.

In natural ecosystems, invasive exotics are a threat to native vegetation through displacement and shading. Because, in general, introduced plant species support an impoverished insect fauna compared to that of native plant species, large-scale replacement of natives by naturalised species is likely to lead to higher-order effects, such as reducing the food supply of endemic birds.

Both Carlström (1996a) and Fleischmann (1997) attempted to identify species most threatening to native vegetation in Seychelles (particularly, the larger islands). Twenty-six invasive plant species thought to threaten native habitats are listed by Carlström (1996a) including one fern, two grasses, 10 shrubs and 13 trees. However, this list includes several species of doubtful origin including one tree regarded by Friedmann (1994) as native (*Trema orientalis*) and one grass regarded by Robertson (1989) as native (*Brachiaria umbellata*).

Fleischmann (1997) regarded 34 introduced species as invasive in his survey of Mahé and Silhouette; most of these species were trees, but seven shrubs, three climbers, a bamboo and two herbaceous species were also included. Fleischmann's list included one native species, *Cocos nucifera,* which probably showed restricted distribution prior to human colonisation. The two lists share 15 species in common, and both suggest that the greatest threat to native ecosystems (at least on large islands in Seychelles) comes from cinnamon *Cinnamomum verum* and Chinese guava *Psidium cattleianum.* However, both earlier lists are primarily concerned with invasive species in native forest habitats of the larger islands (Mahé and Silhouette in the case of Fleischmann, 1997). On smaller, drier islands, the relative importance of different weed species is likely to differ.

In order to assess the weed status of introduced species on smaller islands of the granitic Seychelles, data from plant species lists and vegetation plots were used to provide a measure of distribution and density of populations. While introduced species form a significant part of the flora of smaller islands, most are not widespread; 98 of 295 species recorded in species lists (33%) were found on only one of 11 islands. Only 58 species (20%) occurred on six or more islands. Many of the introduced species are ornamentals which may persist if cultivation were abandoned (as in the case of *Codiaeum variegatum* which survives around the ruins of the leper colony on Curieuse Island), but are unlikely to actively spread into near-natural vegetation. Ornamentals seem less of a threat to natural ecosystems than species introduced for economic purposes; only two of the invasive species listed by Fleischmann (1997) are likely to have originated as ornamentals (*Acalypha wilkesiana, Lantana camara*).

Data from vegetation plots identify those species that have successfully entered near-natural plant communities on a wider scale. Figure 3 shows measures of distribution between 10 islands and within islands (for islands on which species present, percentage of random vegetation plots in which the species was recorded) for all species which are definitely, or probably introduced (definitions of introduced status from Friedmann, 1994). In addition, *Cocos nucifera* was included as its present distribution is largely the result of plantation agriculture of the nineteenth and twentieth centuries. Species are divided by life-form, as this has a bearing on the relative importance of species as weeds: trees, shrubs and large lianas are more likely to reach pest status in woodland and scrub

habitats. Species found in 20% or more of vegetation plots on islands on which they occur are identified.

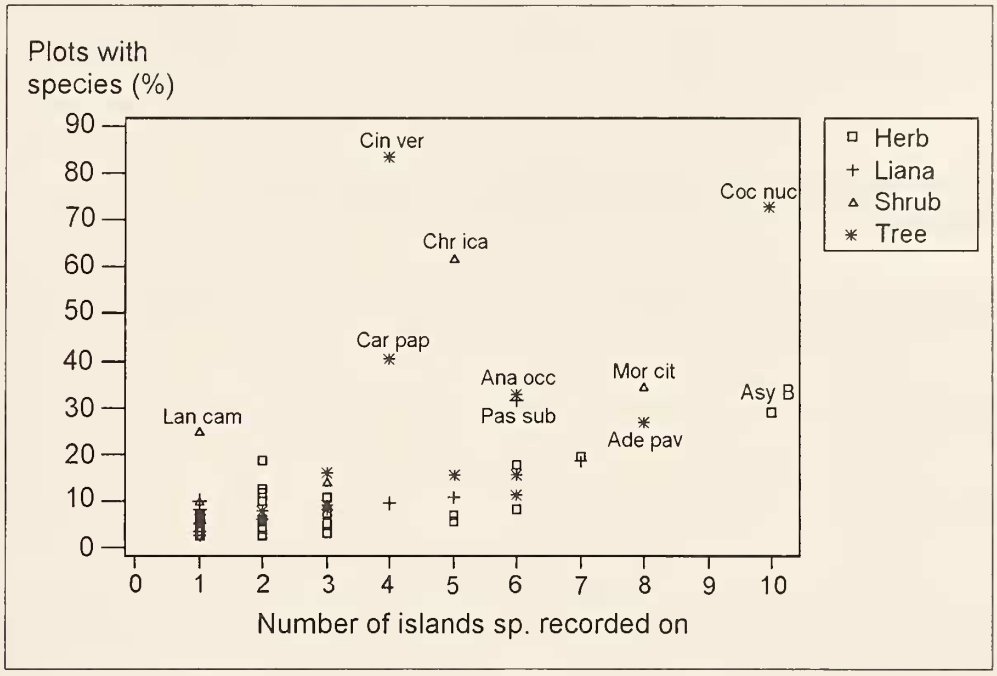

Figure 3. Distribution of introduced species between and within islands.

These data suggest that the most invasive alien species on small islands are *Cinnamomum verum* (Cin ver) and *Chrysobalanus icaco* (Chr ica). *Cocos nucifera* is ubiquitous and regenerates strongly to form a dense scrub of little value to endemic species. *Asystasia* "species B"(*sensu* Friedmann, 1994) occurs on all islands but its impact is probably minor. *Lantana camara* (Lan cam) was recorded in species lists from several islands but only occurred in vegetation plots on one island (North). It is a fast-growing, weedy shrub of open ground that has come to dominate former coconut plantations on North Island but probably cannot survive heavy shade and is not a significant problem in established woodland habitats. The same is likely to be true of *Clidemia hirta,* identified as a weed species on Silhouette and Mahé (Gerlach, 1996a), and a recent invader of North Island. *Morinda citrifolia* (Mor cit) is doubtfully native (Friedmann, 1994; Gerlach, 1996b; Sauer, 1967), supports an extensive insect fauna and has fruit favoured by feeding giant tortoises. *Psidium cattleianum* (P. littorale), identified by Fleischmann (1997) as the second most prominent invasive species on Silhouette and parts of Mahé (after *Cinnamomum verum*), was only recorded in vegetation plots on two islands where it occurred in six (of 77) plots surveyed. In all, only four trees of over five metres were recorded.

The vegetation plot analysis suggests that a small number of (mainly) woody species are the major invasive plants of conservation concern, at least in near-natural woodland and scrub habitats. Vegetation plots were not carried out in other habitats, most notably glacis, a naturally open habitat threatened by a small number of invaders including *Alstonia macrophylla* (Carlström, 1996a), and freshwater habitats. The latter

support a range of exotic species that have become pests in parts of Seychelles, including *Pistia stratiotes, Eichornia crassipes* and *Ipomoea aquatica* (Stevenson *et al.*, 1997).

Data on introduced weeds are summarised in Table 6, showing species in four categories:

a) those woody species which are currently widespread and invasive;

b) species which have the potential to become widespread weeds but are currently restricted in distribution (from Carlström, 1996a; Fleishmann, 1997);

c) species which are potentially invasive in open, glacis habitats (from Carlström, 1996a; Fleishmann, 1997; Friedmann, 1986; and personal observation); and

d) species which are potentially invasive in wetlands (from Stevenson *et al.*, 1997).

Species which were not recorded on any island (probably restricted to the larger islands) are omitted.

In general, coralline islands and small islands have the lowest score for invasive species. The highest scores were for larger granitic islands with a history of cultivation. The lowest score on any of the granitic islands was for Cousin (a nature reserve) but the island of Marianne also had a relatively low score. Marianne had a wide range of weeds but several species (such as *Cinnamomum*) were only present in small numbers and *Chrysobalanus* appeared to be absent.

Table 6. Introduced invasive plant species on the islands assessed.
For island names, see Table 5.
Extent of invasion:
1 = present in small numbers (usually less than 100 individuals per island);
2 = 100-1000 individuals, strong regeneration from seed or vegetative propagation, species dominating small areas of habitat to the exclusion of native species;
3 = very invasive (1000+ individuals, very strong regeneration, large proportions of island dominated by the species, to the exclusion of native species).

	Bir	Con	Cou	Cur	Den	Fel	GSo	Mar	Nor	The
Woody species invading woodland and scrub habitats										
Adenanthera pavonina		2	1	2	2	2	2	1	2	2
Anacardium occidentale		2		2		2	1	1	2	2
Carica papaya	3		3	2	3	1	1	1	1	2
Chrysobalanus icaco		2		3		3	3		2	3
Cinnamomum verum		3		3		2	3	1		3
*Cocos nucifera**	3	3	2	3	3	3	3	3	3	3
Lantana camara					2				3	1
Passiflora suberosa	2	2		2	2	2	2	2	2	2
Species potentially invasive of woodland or scrub habitats										
Clidemia hirta									1	
Psidium guajava				1	1	1	1	2	3	1
Psidium cattleianum		1							2	1
Paraserianthes falcataria				2					2	1
Syzygium jambos		2								
Vanilla planifolia		2		2	2	2	2	2	2	2
Species potentially invasive of glacis or open habitats										
Alstonia macrophylla		2		2					3	2
Ananas comosus		2	2	2		2	1	1	1	2
*Dicranopteris linearis**				3		2				2
Furcraea foetida		2		2	1	2	1	1	2	2
Panicum maximum		2	1	1	2	2	2			2
Species potentially invasive of wetlands										
Ipomoea aquatica							2		1	
Total	8	27	9	32	18	26	24	15	32	33

* Native or doubtfully native species: see Gerlach (1996b), Friedmann (1994).

Pollutants and Pathogens

Pollution and the presence of pathogens all have an impact on individual native species. In some cases, pollutants have been identified (or inferred) as major contributors to a decline in endangered species. On Mauritius, it has been suggested that declines in the populations of the endemic Kestrel and Cuckoo-shrike were caused by the use of organochlorine pesticides (Safford and Jones, 1997). In Seychelles, a range of persistant organic (and inorganic) compounds were used in the twentieth century for pest control on plantations. There is little evidence regarding the levels of use although it is likely that usage in Seychelles was less intense than in Mauritius.

A range of natural pathogens are important to individual species, and thus to habitats. An example is the wilt disease of takamaka *Calophyllum inophyllum*, probably caused by the fungus *Leptographium calophyli* (Ivory *et al.*, 1996; Wainhouse *et al.*, 1998). Takamaka is a native tree, which commonly grows at beach crests, helping to protect them from erosion (for example, on Mahé, Praslin, Curieuse, Grande Soeur). It often forms dense stands in coastal plateau forest (on La Digue, Curieuse, North Island), and occurs in hill forest (on Marianne, Grande Soeur, Curieuse). The wilt fungus causes extensive wilting and dieback of takamaka trees, and can lead to complete defoliation and death of trees within months (Ivory *et al.*, 1996). Wilt disease was first noted on Mahé in 1994, but has now spread to a number of islands (Hill *et al.*, in prep.), some of which have lost many of their takamaka trees (see Table 7). The endemic bark beetle *Cryphalus trypanus* probably acts as a vector of the disease (Wainhouse *et al.*,1998).

Table 7. Current status of takamaka and takamaka wilt disease on islands studied. From Hill *et al.*, in prep.

Island	Takamaka	Wilt disease
Bird	Only one or two trees, planted	Absent
Conception	Occasional component of hill woodland	Absent
Cousin	Few trees	Absent
Curieuse	Many trees, large areas of takamaka forest on plateau and trees in mixed hill woodland	First symptoms observed 1999, extensive death in one area of forest
Denis	Few trees	First symptoms observed 2001
Félicité	Important component of hill woodland	Absent
Grande Soeur	Important part of hill woodland, old trees present on beach crest	Absent
Marianne	Significant component of hill woodland	Absent
North	Many trees, large areas of takamaka forest on plateau and trees in mixed hill woodland	Present, causing death of hundreds of trees
Thérèse	Found in hill woodland, old trees present on beach crest	Present. Most beach crest trees dead, trees on hill survive

Takamaka is one of the most widespread native trees in the archipelago and is a component of near-natural ecosystems on most of the small islands. Loss of trees to takamaka wilt is of particular importance on islands where it forms a major component of plateau woodland, for example, La Digue and North Island. On both these islands, takamaka and badamier *Terminalia catappa* dominate plateau woodland but many mature takamaka trees have been affected by the disease. The longer-term effects of takamaka wilt are unknown; there is some evidence that a proportion of trees recover without human intervention (FAO, 1997). In areas of high landscape value on large islands, trees have been treated with fungicides but this is a labour-intensive and expensive method inappropriate for use on a larger scale. Early eradication attempts and the introduction of regulations prohibiting the inter-island transfer of takamaka wood may have had some effect in delaying the establishment of the disease on the second largest island of the

granitic Seychelles, Praslin, but personal observation suggests that takamaka wilt is now well established there.

A second novel wilt disease affecting sandragon *Pterocarpus indicus,* has recently been recorded on Mahé (Seychelles Nation, 8th May 2000). Sandragon is an introduced tree and is less widespread on smaller islands than takamaka so the disease is of less conservation concern than takamaka wilt but on certain islands (such as Frégate), sandragon is an important component of woodland vegetation.

The source of such novel pathogens in Seychelles is unknown (Ivory *et al.* 1996) but once introduced even strict quarantine measures seem unable to control the spread of virulent pathogens to a large number of islands. While it seems likely that higher levels of human movement between islands increases the risk of transfer of pathogens (probably accounting for the appearance of takamaka wilt on Denis, a remote coralline island), diseases can reach even relatively remote uninhabited islands such as North Island. The true threat to native species and ecosystems from such factors is difficult to predict and resolve.

CONCLUSIONS: ASSIGNING CONSERVATION VALUES

A range of biological and physical factors considered above are summarised for each island surveyed in Table 8. The aim of the table is to illustrate the overall conservation value of each island, including both potential (rehabilitation) values and existing values. Some of these values (size of island and plateau) are unchanging whereas others (number of alien animals, invasive weeds, extent of semi-natural vegetation) may be increased by active management.

Large granitic islands, and coralline islands, emerge as having particularly high conservation values in this simple ranking. The largest islands, such as Curieuse and Félicité, have a wide range of native habitats and relatively large areas of plateau forest which would be suitable for introduction of Seychelles magpie-robin (and possibly black paradise flycatcher). In both cases, existing biodiversity values are high so the removal of introduced vegetation and other conservation management would protect a range of endemic forms.

The coralline islands Bird and Denis were both severely impacted by guano mining and coconut planting in the twenticth century (Stoddart and Fosberg, 1981) and today are dominated by former coconut plantations, although Denis has large areas of badamier *Terminalia catappa* woodland and Bird has some *Pisonia grandis*. While both islands have introduced crazy ants, on Denis these occurred in a restricted area and could be controlled. On Bird Island, the infestation is extensive and is having a serious effect on biodiversity.

Both coralline islands appear to be outside the natural range of many of the endangered endemic birds of Seychelles. The only endemic species to have been recorded on the coralline islands are a sunbird *Nectarinia* sp. (Stoddart and Fosberg, 1981) and Seychelles blue pigeon *Alectroenas pulcherrima*. While reconstructing former ranges of birds is difficult as early ornithological records for the Seychelles are sketchy before 1865 (Rocamora and Skerrett, 2001), it seems likely that few of the granitic Seychelles endemic birds were ever present on the close coralline islands. However,

coralline islands appear to be suitable for some of the endemic land birds and previous translocations of endemic birds to coralline islands within the Seychelles have been successful. The Seychelles magpie-robin survived for over 50 years on the coral island of Alphonse before being exterminated by introduced predators or habitat change in the mid-twentieth century (Collar and Stuart, 1985) and the Seychelles fody was translocated to D'Arros in 1965 (Penny, 1974), where the species survives (BirdLife International, 2000). The eradication or control of alien predators and rehabilitation of woodland habitats dominated by native tree species would increase the likelihood of success of such translocations. Translocations to coralline islands could be used as part of a strategy to extend the range and increase populations of endemic birds requiring less intensive input than captive management.

The remoteness of the coralline islands from the central granitics could be advantageous (allowing isolation from diseases) but would also act as a barrier to natural recolonisation of further islands.

Table 8. Overall island rankings based on criteria discussed above.

	1	2	3	4	5	6	Total	Total rank
Bird	5	2	3	10	1	1	22.0	2
Conception	9	10	9.5	4	7	8.5	48.0	10
Cousin	10	5	5	7.5	2	2	31.5	5
Curieuse	1	4	1	1	8.5	3.5	19.0	1
Denis	4	1	4	9	4	3.5	25.5	3
Félicité	2	6	2	2	6	8.5	26.5	4
Grande Soeur	7	7	6	6	5	5	36.0	7
Marianne	6	9	8	5	3	8.5	39.5	8
North	3	3	7	7.5	8.5	6	35.0	6
Thérèse	8	8	9.5	3	10	8.5	47.0	9

1 = size of islands. 1=largest, 10 = smallest
2 = area of true coastal plateau: 1 =large, 10 = small
3 = area of existing near-natural habitat: 1= large, 10 = small.
4 = existing number of endemic/threatened plant species: 1 = many, 10 = few
5 = score for existing introduced weed species: 1 = few, 10 = many
6 = existing number of introduced animal species: 1 = few, 10 = many

Although Cousin is already managed for conservation and has a high proportion of its land area under semi-natural forest, its small size means that it does not emerge strongly in this particular analysis. North Island, although much larger with a larger plateau, ranks lower overall because most of its near-natural habitat has been lost over the island's long history of human use. North Island's existing biodiversity values are low. A small proportion of the flora is native and there are only two endemics. However, given active management for conservation, its potential value for conservation of a variety of endemic birds is high.

The small, rocky islands of Thérèse and Conception are identified as having the lowest rehabilitation values. These islands are predominantly open rocky hills with a high

proportion of glacis. However, despite the island's small size and dominance by introduced species, Conception supports the major population of one of Seychelles' endangered endemic bird species, the Seychelles white-eye *Zosterops modestus*. Were introduced predators to be eliminated and habitat rehabilitation to be implemented, both of these smaller islands could support small insectivorous bird species such as Seychelles warbler and white-eye. While populations would necessarily be smaller than those on larger islands, the founding of new populations would in itself reduce the likelihood of extinction of these species. Both Therese and Conception support a number of endemic plant species absent on much larger islands because they are positioned relatively close to Mahé, the largest island of the archipelago and one of the islands having the greatest endemic biodiversity. While limited resources available to conservation might be better directed at medium-sized islands with large plateau areas that could support a number of endemic species, under appropriate management regimes even the smallest of the islands surveyed could have a role in the conservation of Seychelles endemic land birds.